CHEMERGY

Recovering Hydrogen from Wet-Biowaste

An Introduction to HyBrTec

Our future can be greener and cleaner by eliminating a problem with biowaste. Chemergy's patented HyBrTec process recovers hydrogen from: sewage, manure, municipal solid waste, agricultural residuals, paper, kitchen & yard waste, and even plastics. These wastes have negative-value, are regulated environmental pollutants and are an escalating economic burden to industry, commerce and the public.

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Safe Harbor Provisions

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Recovering Hydrogen from Wet-Biowaste

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"Let's Stop Wasting Waste":

Chemergy's HyBrTec technology produces low-cost renewable hydrogen (H_2) from organic biowaste eliminating the economic and environmental burden of wet-biowaste processing and disposal. HyBrTec promotes a C^4 paradigm shift from:

1) Costly non-renewable resources to negative-valued renewable wastes,
2) Capital intensive large central plants to distributed and mass-produced systems,
3) Collecting and transporting feedstock to using it onsite where produced,
4) Climate changing fuels to climate neutral H_2.

In 1911 GE introduced a home refrigerator, which then cost twice as much as a car and did not provide a return on investment; however, its convenience doomed the centralized ice houses and their delivery infrastructure. The process discussed herein when mature will present a convenient, cost effective, and environmentally sustainable method for converting wet organic biowaste into renewable H_2.

Opportunity:

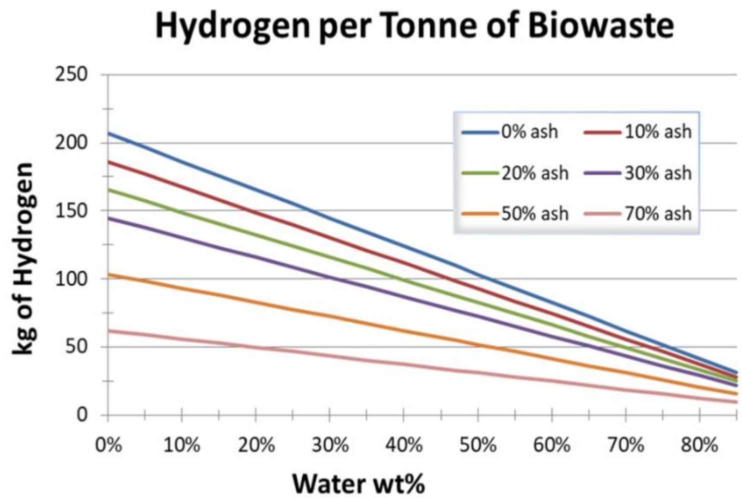
In the U.S., waste-water treatment plants (WWTP), municipal solid waste, confined area livestock feeding operations, agriculture and food processing produce over 1 billion tons of biowaste annually, which requires from \$40-\$200 per ton to treat and dispose of. The amount of biowaste and its processing costs continue to increase.

Roughly 3% of total U.S. electricity consumption is used for the collection and treatment of water and wastewater, and this sector is responsible for emitting more than 45 million tons of greenhouse gas (GHG) annually. WWTP in the U.S. produced 7.9 million tons of biowaste in 2014, and the latent energy in this biowaste could meet 12% of the nation's electricity demand.

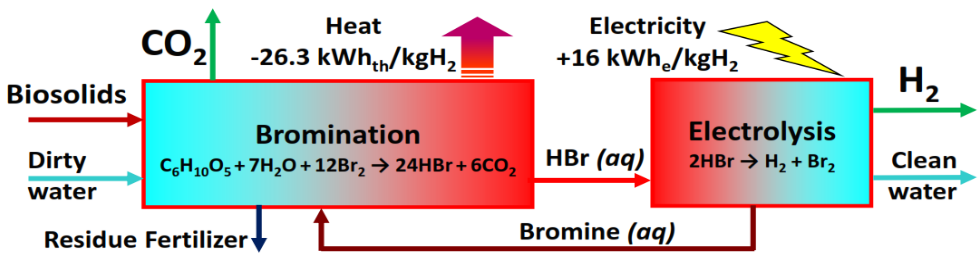
Fuel and electricity represent a substantial cost to WWTP; an energy expenditure is required for nearly all stages in the treatment process, from the collection of raw sewage to the disposal of dried solids and discharge of treated effluent. In contrast to being a public economic, energy and environmental burden, HyBrTec technology allows WWTP to be energy independent producers of energy and renewable fuel. Due to water shortages, higher energy and capital costs and a changing climate, water-energy issues are of growing global importance.

HyBrTec Processing:

Organic biosolids contain an unused remnant of stored solar energy that HyBrTec processing recovers as H_2, carbon dioxide (CO_2), thermal energy and inorganic ash. Feedstocks include: sewage, manure, wood and agricultural residuals, paper, plastics and municipal solid waste. The amount of recoverable H_2 depends on the water and ash content of the feedstock but ranges up to 200 kilograms of H_2 per ton of biowaste as shown below for different ash and water contents.

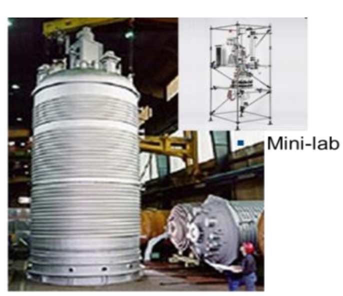


Processing wet-biowaste, HyBrTec capitalizes on two established steps that are scalable from pounds to tons per minute with commercially available equipment. First, cellulosic biowaste and wastewater ($C_6H_{10}O_5$ & H_2O) are 'burned' or oxidized with bromine (Br_2) to produce hydrogen bromide (HBr), carbon dioxide (CO_2) and heat. The HBr reacts with unreacted water forming concentrated hydrobromic acid (HBr_{aq}), and this bromination is followed by electrolysis of the HBr_{aq} into H_2 and reagent Br_2 that is recycled back into the process as illustrated below.



Unique to HyBrTec is that 175°-200°C heat is released in bromination that can be used in pasteurization and distillation processes or to reduce the original as received feedstock water content to a desirable 50%. Also, electroosmotic water transfer from the Br_2 anode to the H_2 cathode increases the acid concentration at the anode, which lowers cell voltage and results in 4-6 gallons of potable water per kg of H_2. Byproduct CO_2, which is organic in origin and not considered a greenhouse gas, can be vented or used to synthesize other commodities including conventional liquid fuels including ethanol or diesel. The inorganic ash residual is suitable for use as a micro-nutrient fertilizer.

As illustrated at right, all components are commercially available, allowing the HyBrTec technology to be scaled-up from a residential appliance processing kg/day to commercial and agricultural applications processing tons/day to municipal WWTP and solid waste plants burdened with 100's of tons of wet-biowaste daily.



- Glass-lined reactors
  - 1 to 20,000 gallon

- Electrolysis stacks
  - kW to many MW systems

Conventional Hydrogen Production:

Most fossil-based H_2 is produced by steam methane reforming (SMR) and renewable H_2 from the electrolysis of water. Without considering plant efficiency, capital or operating costs, H_2 from SMR has a minimum value of 1.45 times the price of methane. In addition, for every ton of H_2 produced, 10 tons of greenhouse-gas CO_2 are co-produced and released from the feedstock and processing. The electrolysis of water requires a clean, pure feedstock and requires considerably more energy than what H_2 will produce when reacted with oxygen (air).

Conventional Biofuel Production:

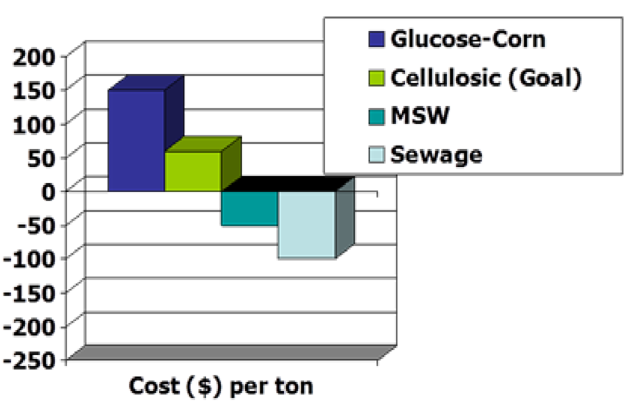
Methods for producing biofuel, fermentation and anaerobic digestion are proven, well-established and well-financed processes; however, often the biofuel is produced from higher-value products such as corn and sugar. Anaerobic digestion uses decaying organic material to produce a H_2-rich syngas, which is used where there is waste that needs treatment or significant subsidies for using energy crops.

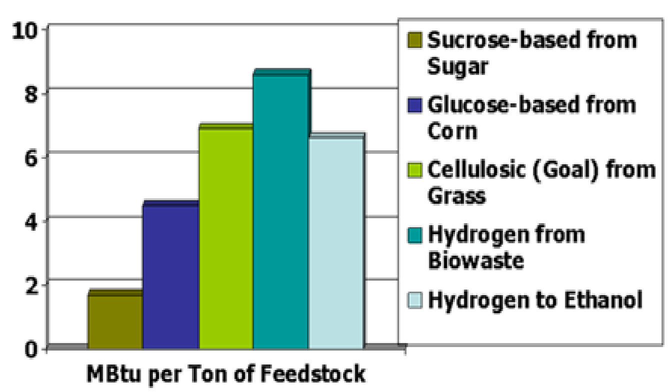
Fermentation is a slow process requiring 'bugs' (yeast) and heat for distillation that has been producing beer, wine and alcohol for thousands of years from cultivated crops. Now it's used to produce ethanol from corn and sugar, impacting feed and food costs:

- Subsidies cost U.S. taxpayers $40 billion annually
- Reduced energy content cost drivers $10 billion annually
- Increased food cost consumers $3.5 billion annually
- Requires 29% more energy to refine than gasoline

To quiet the "food vs. fuel" debate, effort is now directed at cultivating algae and grass feedstock. Yet, cultivation of feedstock still requires fossil-fuel for planting, fertilizing, harvesting, transporting and distillation of product, which without subsidies would be unprofitable in the U.S. and even with subsidies there have been many failures.

Anaerobic digestion and fermentation both use biological microorganisms ('bugs'), which are temperature dependent, require large volumes with slow rates and low yields, and are prone to contamination (sulfur) or conditions (temperature) that kills the 'bugs' employed to do the work. And, as illustrated below, conventional biofuel producers pay for crop feedstocks whereas biowaste producers pay for biowaste disposal; yet, biowaste can produce more fuel than crop feedstocks.



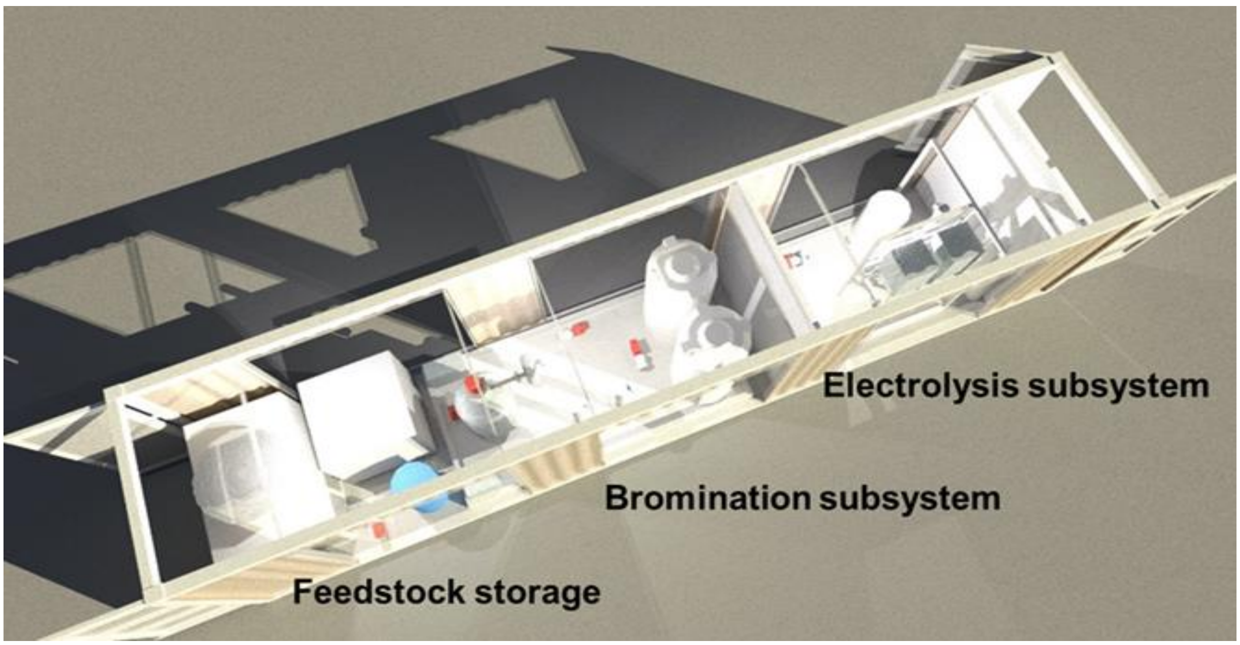


Development Programs:

Beginning in 2010 the U.S. Department of Energy (DOE), and the Florida Hydrogen Initiative funded laboratory bench-top R&D of HyBrTec. Based on the success of this research and at the recommendation of Lawrence Livermore National Laboratory (LLNL), the California Energy Commission (CEC) funded Chemergy in a cost-shared program in 2013 to:

1) Experimentally determine suitability of biosolids from the Delta Diablo WWTP,
2) Prepare a detailed system design and cost estimate of a pilot demonstration, and
3) Forecast a financial analysis of a commercial system.

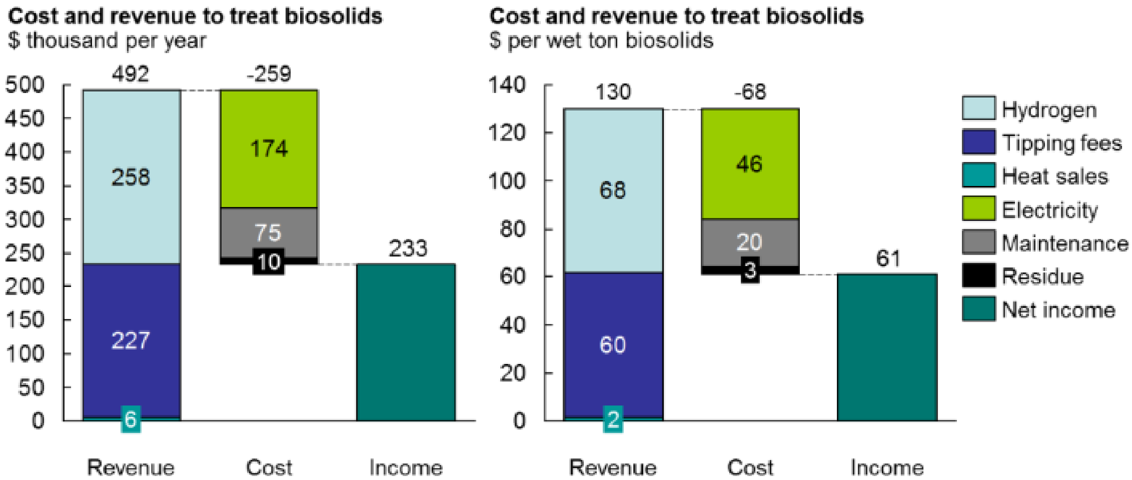
Chemergy's team included: Delta Diablo WWTP, LLNL, ETC, EnStorage, O'Brian & Gere, Harris Group, Albemarle, and Taiji USA, which designed and specified an integrated system capable of processing 0.5 ton/day (8 hours of testing and evaluation). The demonstration system was to be housed in a 40' ISO container shown below.



The results of the CEC program verified that 100 kg of H_2 could be recovered from a dry-ton of Delta Diablo biosolids at reasonable reaction temperature and duration. Experiments also showed an 80% reduction of dry biowaste mass or 95% from the wet-mass, with processing. The program also verified the low-voltage (<1 Volt) reported in the literature and by the Savannah River National Laboratory for HBr_{aq} electrolysis (SRNL Contract # DE-FC36-04GO14232) which is over 50% less than the 2+ Volts required for water electrolysis.

Process Economics:

The financial analysis assumed \$2/kg production and \$3/kg wholesale price for H_2, which does not include retail costs of compression, storing and dispensing and is the DOE production cost target for 2020. The revenue, cost and income of a \$1.5 million capex plant processing 11 wet-ton of biosolids daily is shown below.



Cost and Revenue for 11 wet-ton/day HyBrTec System

Three financial metrics were used to predict how HyBrTec will perform economically: Internal Rate of Return (IRR), Net Present Value (NPV) and straight payback period. The analysis predicted a 14% IRR, NPV of $1,168,000 over a 20-year lifetime with a 6% discount rate and a payback period of 6.4 years. *Benefits from increased scale, energy storage, state and federal incentives, loan guarantees, cap and trade credits and subsidies are not included.*

HyBrTec Hydrogen as an Alternative Transportation Fuel:

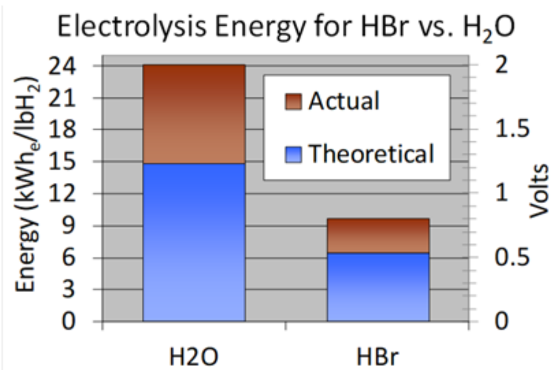
The major automobile manufacturers are developing H_2 fueled-vehicles with Hyundai, Toyota and Honda leasing and selling vehicles today. California has 40 refueling stations in operation and 100 planned by 2023 as an alternative to gasoline.

The U.S. EIA reported that in 2018 almost $400 billion was spent on ≈143 billion gallons of gasoline at an average cost of $2.79 per gallon. This consumption released over a trillion tons of CO_2 or ≈30% of U.S. emissions. The price of gasoline includes: 1) crude oil 59%, 2) taxes 16%, 3) refining & profit 13% and 4) distribution and marketing 12%. With gasoline at $2.79 per gallon, the energy carrier, crude oil represents ≈$1.65 of the gallon's cost. A gasoline-fueled vehicle with an internal combustion engine (ICE) is ≈20% efficient. Therefore, from a $1.65 cost in oil for a gallon of gasoline, ≈$.33 provides work with a loss of ≈$1.32 in the cost of crude oil. In contrast, an electric vehicle (EV) with a H_2 fuel cell providing electricity is 40-60% efficient, providing over a 50% reduction in fuel consumption compared to an ICE vehicle.

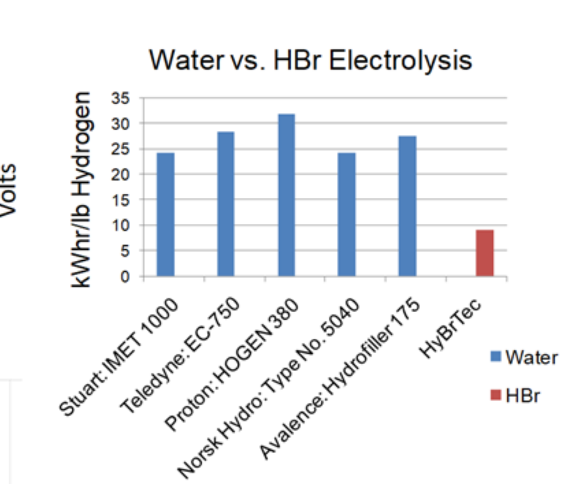
HyBrTec requires 16-18 kWh of electricity (≈68% of cost) to produce a kilo of H_2 with the Btu equivalent of a gallon of gasoline (gge). With utility-scale wind and solar PV approaching $0.05 per kWh, HyBrTec will produce a kilo of H_2 for ≈$0.85 of renewable electricity. In a 50% efficient EV H_2 would provide ≈$0.42 in work, with a loss of only ≈$0.42 in electricity compared to the $1.32 loss in crude oil fueling an ICE vehicle. The 2018 $400 billion expenditure in gasoline did not address "well-to-wheels" environmental or health issues. With H_2 from renewable resources and energy "well-to-wheel" issues are no longer relevant. With an energy cost of half that of 2018 crude oil ($1.65 of crude oil vs. ≈$0.85 of electricity), ≈143 billion gallons of gasoline costing ≈$236 billion in crude oil could be replaced with ≈72 billion gge of H_2 produced from wet-biowaste for ≈$61 billion in renewable electricity fueling a 50% efficient H_2 fueled EV.

Process Efficiency:

LLNL used Engineering Equation Solver (EES) software to model and project the mass and energy balance, which predicted a high system thermodynamic efficiency of 56%. However, biowaste-to-energy efficiencies exceeding 100% are possible by omitting the carbonaceous fuel value of the biowaste and the thermal energy produced in its exothermic bromination reactions. As illustrated below, this is because the theoretical voltage (or energy) to dissociate H_2 carrier HBr into H_2 and Br_2 (0.58 Volt) is less than the voltage (and energy) produced in the H_2 reaction with $½O_2$ (1.23 Volt) forming water.

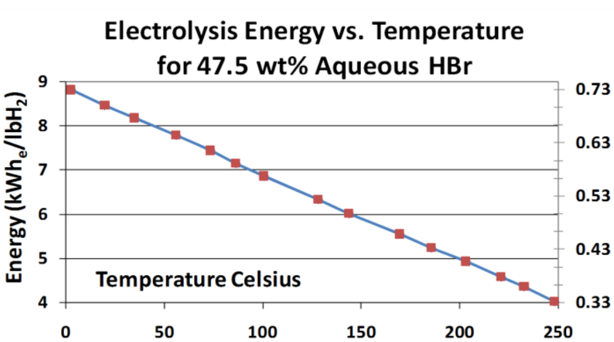


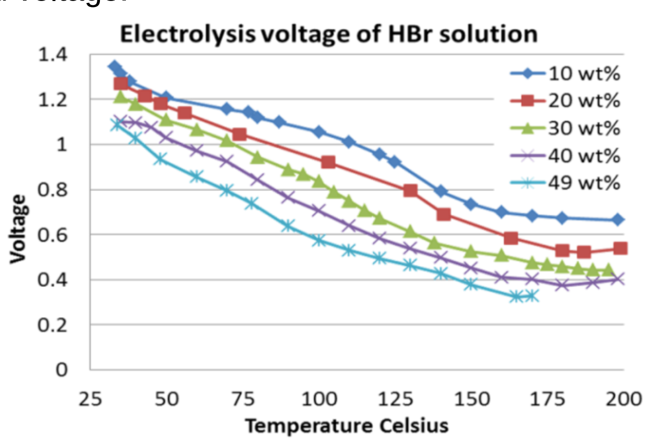
- H_2O electrolysis requires distilled pre-treated water
- HBr electrolysis improves with conductive contaminates in the electrolyte



Summary of Electrolytic Hydrogen Production (Water Electrolysis), September 2004, NREL/MP-560-36734

Consequently, the *theoretical* biowaste-to-energy efficiency is 212% (1.23V/0.58V). However, if the electrolyzer operates at 0.8 Volts the efficiency is 154%; if the H_2 is used in a 65% efficient fuel cell with air the electric-to-electric efficiency is reduced to 100%. The efficiencies above disregard the latent energy content of the negative-valued biowaste feedstock, which if included yields a wet-biowaste-to-electricity efficiency of 67%. As shown below left, the electrolysis of HBr_{aq} is dependent on electrolyte temperature, affording reduced voltages at elevated temperatures which can be achieved using the bromination thermal energy to heat and concentrate the HBr electrolyte. Also, as shown below right, along with temperature, the required electrolysis voltage of the acid is dependent on the concentration of the electrolyte with higher concentrations reducing the required voltage.

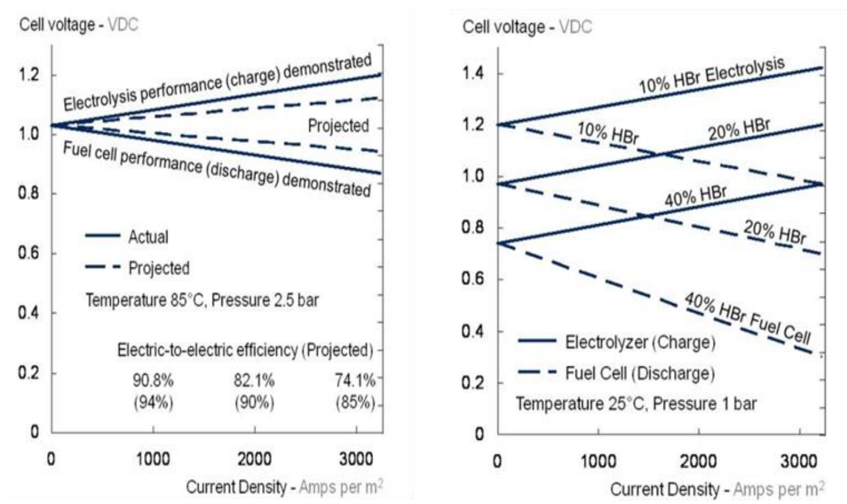




Energy Storage:

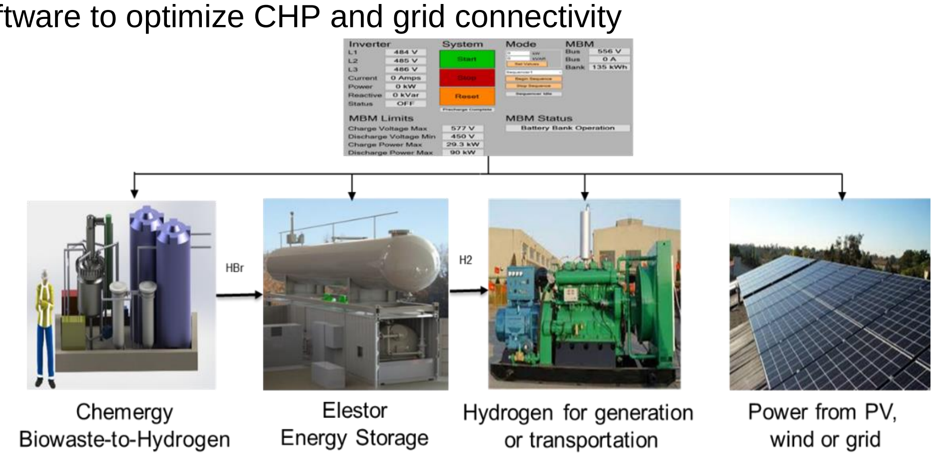
HBr_{aq} electrochemical cells are reversible ($2HBr \leftrightarrow H_2 + Br_2$), able to store electricity by electrolyzing HBr into H_2 and Br_2, which converts electrical energy into stored chemical energy and later producing electricity as a fuel cell converting the stored chemical energy back into electrical energy by recombining H_2 and Br_2. During the late '70s and early '80s Brookhaven National laboratory (BNL) and General Electric Co. (GE) developed the H_2-Br_2 'flow-battery' as an electrochemical break between the electric grid and missile silos to provide silo EMF isolation and store required mission energy. In a 'flow-battery' power (kW) is determined by the cell-stack capacity and energy (kWh) by the amount of externally stored H_2 and Br_2. The H_2-Br_2 flow-battery is now being commercially developed by Elestor https://www.elestor.nl/ in the Netherlands.

The BNL/GE charge vs. discharge voltages graphed at right show electric-to-electric efficiencies greater than 100% are possible with HBr reversible electrochemistry. Adding HBr from the HyBrTec bromination processing will keep a high (40%) concentration during the electrolysis or charging cycle ($2HBr \rightarrow H_2 + Br_2$), which will maintain a low (<1V) charging voltage. During the fuel cell cycle ($H_2 + Br_2 \rightarrow 2HBr$) adding water and electroosmotic transfer will lower HBr concentration (10%) retaining a high (>1V) discharge voltage.



Expand Distributed Micro- Smart-grid Advantages:

1) Eliminate the economic and environmental cost of biowaste processing and disposal
2) Provide low-cost renewable H_2, thermal energy and efficient energy storage
3) Promote small-scale and well-distributed solar, wind, and genset-fuel cell resources
4) Mitigate cyber-attacks, weather-disruptions, demand-instability, and cost-fluctuations
5) Software to optimize CHP and grid connectivity



https://cleantechnica.com/2020/02/22/usa-braces-for-tsunami-of-microgrids-as-defense-dept-wades-in-cleantechnica-exclusive-interview/

Next Step, Pilot Demonstration:

To take the HyBrTec process to the next Technical Readiness Level (TRL-6 Prototype system verification) and TRL-7 (Integrated pilot system demonstration), Chemergy is planning to build, test and evaluate a pilot demonstration capable of daily processing 1 wet-ton of assorted feedstocks under various conditions. All components, including feedstock preparation, reactors and electrolysis stacks are commercially available. With the exception of the reactor, all processes are at low temperature (175^{o} C) and pressure (100 psi).

Biosolids are a byproduct of WWTP. Florida has over 315 WWTP that in 2019 landfilled over 65,500 dry-tons (~330,000 wet-ton) of biosolids, whose nutriment run-off into surface waters promotes algae growth 'blooms' that contaminate Florida's waterways and coasts. This leads to massive coastal pollution that impacts Florida's essential seafood, recreation and tourist economies and kills sea-life as illustrated below.

In 2007 Florida legislation gave the waters of South Florida special protection by banning the landfilling of biosolids. Since then Miami-Dade Water and Sewer Department (MDWASD) has trucked north over 90,000 dry-tons of biosolids. MDWASD produces over 530 wet-tons (~100 dry-ton) of biosolids daily at a tipping cost of $50-60/ton.

Under Florida Governor DeSantis' program to mitigate or eliminate algae growth in Florida's waters from landfilling biosolids, Chemergy teamed with MDWASD submitted a $2.3 million proposal to the Florida Department of Environmental Protection (FDEP) to demonstrate the recovery of H_2 from biosolids. In January 2020, the FDEP approved the proposal and will fully fund the 2-year program that includes $2 million to Chemergy to design, fabricate and test a pilot system processing biosolids at the MDWASD Virginia Key WWTP. The 2-year program is in two stages: In the first year, $1 million to design, build and start-up a pilot system. Followed by $1 million for one year of testing and evaluating the pilot system at the Virginia Key WWTP.

HyBrTec is projected to recover 100 kg of renewable H_2 with the Btu content of 100 gallons of gasoline equivalent (gge) from a ton of dry-biosolids. For Miami-Dade County alone, commercial modular systems processing 100 dry-tons of biosolids are projected to recover H_2 with the Btu content of 10,000 gge daily. This would eliminate the county's cost and need for gasoline-fueled vehicles and promote zero net energy (ZNE) use in county facilities. With a production cost estimate of $2/kg, HyBrTec will not only eliminate the County's environmental burden of disposal, it will profitably eliminate the public's economic burden.

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In 2019 Florida consumed 22,000 gallons of gasoline daily, or ≈8 million gallons annually that could have been replaced with 4 million kilos of H_2 fueling a fuel cell powered EV. Florida's 65,500 dry-tons of landfilled biosolids could yield hydrogen with the Btu content of 6.5 million gge, which as transportation fuel could eliminate Florida's need for gasoline and greatly reduce greenhouse emissions. Furthermore, processing municipal solid waste, hurricane debris, manure and other agri-residuals along with an energy storage capability afford additional environmental and public economic benefits.

In response to the toxic algae blooms, the Florida 2020 Clean Waterways Act has provisions to minimize pollution including: The FDEP will ensure funds are available for disposal infrastructure improvements to prevent contamination, and to prevent discharges due to power outages from WWTP. *Chemergy's HyBrTec processing will eliminate biosolid contamination by processing into hydrogen and can co-provide energy storage that will mediate power disruptions.*

Pro-forma Forecast for WWTP in Florida:

Public-service WWTP, may have political and policy issues with new capital expenditures for commercially unproven technology. Thus, after the FDEP funded piloting program, Chemergy will purchase and operate pre-commercial systems to initially address Florida's problem. These systems will be designed and assembled to Chemergy's specifications by qualified engineering, procurement, construction (EPC) companies. An est. $1.5 million Alpha system will process 11 wet-ton of biosolids daily. It is anticipated that four Alpha systems ($6M) will be installed by 2023 for on-site testing and evaluation. With validation of the Alpha systems, larger Beta systems will be placed to capture economy of scale benefits and provide a more compelling business case. The est. $3.5 million Beta system will process 44 wet-tons of biosolids daily with six systems ($21M) installed in 2024. Following the scaled-up Beta systems, in 2025 six est. $7 million modular commercial systems ($42M) capable of processing up to 100 wet-ton daily will be installed. The CEC program financial analysis (page 6) allows a 'back-of-envelope' 5-year forecast based on the wet-ton (wt) of biosolids processed that is illustrated below:

System	Total wt/year processed	Systems installed	Revenue ($/wt) 130	Cost ($/wt) 69	Income ($/wt) 61	Year	IRR
Pilot Plant 1 wet-ton/day	-	-	-	-	-	2021-22	
Alpha System 11 wet-ton/day	16,060	4	$ 2,087,800	$ 1,108,140	$ 979,660	2023	16%
Beta System 44 wet-ton/day	112,420	6	$ 14,614,600	$ 7,756,980	$ 6,857,620	2024	25%
Commercial 100 wet-ton/day	331,420	6	$ 43,084,600	$ 22,867,980	$ 20,216,620	2025	29%
5-year Cummulative Total	459,900	16	$ 59,787,000	$ 31,733,100	$ 28,053,900	5-year EBITDA	

The table above predicts that processing the 65,500 dry-ton (~330,000 wet-ton) of biosolids landfilled from 315 Florida WWTP will only require 16 systems with an est. $69 million capex, and produce an income of $20 million providing an annual 29% IRR by 2025. These systems would eliminate biosolid nutriment contamination and restore Florida's water resources and dependent economic industries. The table above does not include economic benefits from energy storage or federal and state financial incentives promoting renewable fuels and low-carbon emission technologies. Once commercially proven, the private sector (agriculture, diaries, etc.) may prefer to purchase systems to meet individual needs. Therefore, in addition to owning, Chemergy will sell EPC fabricated commercial systems with a 30% profit margin. In is anticipated that retail commercial systems will still provide the owner a healthy 20% IRR.

HyBrTec Benefits:

1) HyBrTec processes a negative-value, biowaste feedstock into an essential, high-value chemical commodity H_2, which can be used to fuel vehicles in addition to the traditional 'merchant' H_2 demand for refineries, ammonia, and methanol.
2) Promises to be more efficient, less-expensive, and environmentally cleaner at producing hydrogen than steam-methane reforming and water electrolysis.
3) HBr reversible electrochemistry can provide an energy storage capability, increasing the value of intermittent solar and wind resources and promote micro- and smart-grids that exploit local energy resources, reduce capacity demands and mitigate disruptions.
4) Not only can the HyBrTec process WWTP biosolids, but it is applicable to other waste streams including municipal solid waste, animal manure, food and kitchen waste, agricultural and forest residues, plastics and dedicated algae and grass energy crops.

Critical Risks and Assumptions:

Market deficiencies and its mitigation: If there is an abundance of wet-biowaste but no readily available market or need for H_2, then one kg of H_2 can be combined with nitrogen from on-site membrane air-separation to produce 5.7 kg of ammonia, which is a higher-value chemical commodity and easily transportable. With H_2 readily available, there's a 50-60% reduction in an ammonia plant's capital cost, which lowers the production cost of ammonia. Byproduct CO_2 is bio-carbon and GHG neutral and can be combined with ammonia to produce higher value urea. Other opportunities to monetize the CO_2 byproduct include combining it with H_2, producing methanol, ethanol or methane using Fischer-Tropsch or Audi e-gas processing. Furthermore, H_2 can enrich methane combustion, reducing NOx emissions, or used directly as a fuel, without the GHG CO_2 emissions from natural gas combustion.

Technical deficiencies and its mitigation: The technical challenge of HyBrTec is the use of Br_2, HBr, and H_2. H_2 is well-established as a commodity and is acceptable as an emerging fuel due to new codes and standards. Weakly-bonded HBr is an ideal intermediate hydrogen carrier. HBr_{aq} (hydrobromic acid) is a strong acid because the overlap of orbitals between the H and Br atoms is small, hence the H-Br bond strength is weak and is easily broken. Also, the Br- ion is a relatively stable ion because its negative charge is diffused over large orbitals, reducing charge density. Br_2 is relatively unknown and requires special consideration, but its high thermo- and electro-chemical reactivity makes it ideal for the processes exploited by HyBrTec. Also, Br_2, like chlorine (Cl_2), is a halogen and its safe use follows from the electrochemical systems and procedures used extensively by the chlor-alkali industry without incidents. Furthermore, Br_2 is substantially less toxic than Cl_2, and as a liquid at STP, is much easier to handle than Cl_2 whose use is well-established with municipal water and WWTP.

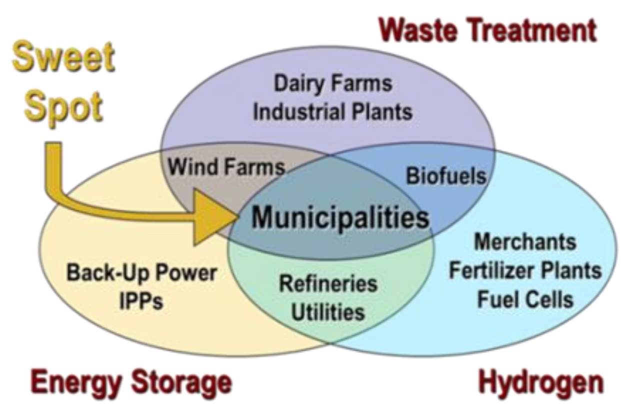
Safety and environmental deficiencies and their mitigation: LLNL has reviewed bromine's safety and prepared *A Survey of Bromine, Industrial, Bromine Safety Practices and Electrochemical Applications,* which concluded: "that bromine and its compounds can be considered safe as a result of standards and practices." Furthermore, both Br_2 and HBr are soluble in water, which is a co-reactant and the storage and transport medium in HyBrTec. This reduces environmental risks of concentrated spills, and eliminates the chance of atmospheric discharge. Br_2 spills are neutralized with soda ash, caustic and potassium hydroxide, while HBr_{aq} is neutralized with limestone into benign calcium-bromide salts.

Regulatory Aspects: Handling biowaste-streams and chemicals will require compliance with well-established requirements, but this will not be prohibitive – regulation is a fact of business for anyone in the biowaste-disposal, wastewater-treatment and H_2 production industries. In California H_2 is an emerging vehicle fuel, GHG reduction and energy storage are already legislated as are future zero net energy building goals. Legislation promoting renewable and carbon-neutral fuel and energy will facilitate HyBrTec's acceptance.

HyBrTec's Competitive Advantages:

- Wet-biowaste feedstock is abundant and an environmental and economic burden.
- HyBrTec exploits two advantages that reduce capital and energy:
  - At moderate temperature and pressure, processing is fast and yields are high, which minimizes the size, footprint and cost of equipment.
  - The chemical bonds to release H_2 from HBr are weak; requiring less than half the energy (40%) then what H_2 will produce when burned with oxygen (air).
- HyBrTec is a highly scalable technology able to process lb/day or tons/minute with commercially available components anywhere biowaste is produced.
- With electricity from renewable solar and wind resources, HyBrTec is GHG neutral.
- H_2 and by-product CO_2 can produce conventional fuels including ethanol, methane, green diesel or higher-valued chemical commodities.
- \$4/kg H_2 fueling a 50% efficient EV is equivalent to gasoline at \$1.60/gallon fueling a 20% efficient ICE vehicle without 'well-to-wheels' environmental and health issues.
- Accrues financial benefits from state and federal renewable-energy tax incentives, loan guarantees, GHG cap and trade programs and electrical energy storage subsidies.

The long-term potential of HyBrTec comes from: 1) eliminating biowaste disposal cost and environmental issues, 2) producing H_2, and 3) storing electrical energy at a scale applicable to a household appliance or to that of a city. As illustrated at right, this profitable triad allows three revenue streams that maximize asset utilization. Applications include power generation, agriculture, oil and gas industries, transportation, and the 'market entry sweet spot': municipal WWTP.



Other Emerging Opportunities:

In addition to the FDEP program with MDWASD, the Saudis have requested a proposal for a pilot plant to process manure at a dairy under the kingdom's KACARE solicitation.
https://en.wikipedia.org/wiki/King_Abdullah_City_for_Atomic_and_Renewable_Energy

Also, California has set goals for zero net energy (ZNE) buildings, which include:

1. New residential construction will be ZNE by 2020.
2. New commercial construction will be ZNE by 2030.
3. 50% of commercial buildings will be retrofit to ZNE by 2030
4. 50% of new major renovations of state buildings will be ZNE by 2025.

Long-term Goal:

Buy hydrogen vehicle fuel? **Or produce it at home?**

Not like GE in 1911 introducing a home refrigerator for convenience. Chemergy's goal is a UL certified appliance that will provide a 15% ROI processing kitchen, toilet, yard and junk-mail into H_2 and heat. A 'bullet-proof' appliance; in the event of a failure the small amount of reagents would be neutralized and contained. This would advance a paradigm shift from consuming valuable non-renewable resources at large centralized plants to recycling and reusing negative-valued waste on-site. The table below is a 'back-of-envelope' cost estimate to develop a home appliance that would cost <$8K to manufacture and retail for <$10K.

Activity	Capital ($M)	Sales ($M)	EBITDA ($M)
Prototype Development (year 1)	(2)		
UL Certified Product (year 2-3)	(4)		
Manufacturing (plant #1)			30% margin
20,000 units/year (year 4)	(10)	158	37
40,000 units/year (year 5)	(2)	316	73
80,000 units/year (year 6)	(2)	633	146
Total	**(20)**	**1107**	**256**

Authors:

Robin Z. Parker, Chairman and CEO Mr. Parker is the past president and founder of SRT Group, Inc. where he directed and managed SRT's research programs with NASA and the U.S. Departments of Defense and Energy from 1984 until 2010. He is also a Registered Architect in the State of Florida. He is responsible for a portfolio of outstanding patents and architecture.

Dr. Melahn L. Parker, President and COO Dr. Parker has a decade of experience analyzing, modeling, engineering and fabricating complex energy systems. He graduated from Stanford University in 2009 with a Ph.D. in Aeronautical Engineering, from Caltech in 2003 with an M.Sc. in Chemical Engineering, from M.I.T. in 2001 with an M. Eng. in Aerospace Engineering, and from M.I.T. in 2000 with B.Sc. degrees in both Aerospace & Chemical Engineering. He has worked at McKinsey & Company, Sandia National Laboratory, Northrop Grumman Corporation, and the Boeing Company; in addition to directing the research and development of the Chemergy processes.